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Urban, F.; Moll, H.C.; Benders, R.M.J.

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Modeling Transitions To Renewable Energy In Developing Countries

F. Urban*, H.C. Moll, R.M.J. Benders

Center for Energy and Environmental Studies IVEM, University of Groningen, Nijenborgh 4, 9747 AG Groningen, The Netherlands
** Corresponding author. Tel.: + 31 50 3637177, E-mail address: f.urban@rug.nl*

Abstract

As a growing share of the future world population is expected to live in developing countries and as rapidly developing countries will soon be amongst the world's hugest consumers of energy, it is essential to acknowledge the increasing influence of the developing world on the global energy future.
Energy models are helpful for exploring the future pathways of regional and global energy developments. However, most present-day energy models are developed for industrialised regions, while neglecting the specific conditions of developing regions. Energy systems in developing regions are different to those in industrialised regions concerning key issues such as differences concerning electrification rates and fuel use, policy frames and economic structural change. Only few present-day energy models take into account these issues. Consequently, our aim is to include these issues in global energy models to adequately represent energy systems of developing regions and their future pathways.

Introduction

This paper discusses the increasing impact of developing countries' growth on global energy consumption. Using examples from India, it further elaborates which requirements need to be fulfilled for modeling energy transitions specifically for developing countries. Modeling energy systems and their future developments is crucial, because models enable the observer to better understand the complexity of the system, to overview the variables and to analyze dynamic interactions. Most energy models focus on industrialized regions, while neglecting the present-day specific conditions of developing regions (1).

Results

As a growing share of the future world population is expected to live in developing countries and as rapidly developing countries will soon be amongst the world's hugest consumers of energy, it is essential to acknowledge the increasing influence of the developing world on the global energy future.
Considering energy modeling, the starting situation for developing countries today is significantly different from the western industrialization. Today, the most accessible and cheapest oil, gas and coal reserves are globally being depleted (2). Concurrence is high for the remaining reserves. Further, climate change and local air pollution pose serious threats to the global environment (3) and human heath. Therefore, to enable energy security and mitigate global climate change, energy transitions towards renewable energies are crucial.
The global potentials for renewable energies are estimated at up to 1,135 EJ/yr for primary biomass, 370 PWh/yr for solar energy and 96 PWh/yr for wind energy, of which a substantial potential is situated in developing countries (4). This potential equals 4x the global present-day energy consumption. As an example, India has the potential for 660 TWh/yr technically and economically feasible energy from hydropower and 45,000 MW wind energy while only 82 TWh hydro were generated in 1999 and only 1,175 MW wind energy were installed in mid-2000 (5). Despite the significant unused potential of renewable resources, economic, legislative, policy-related, social and technical obstacles exist which hinder the exploitation of these resources.

For developing strategies of how to reduce these obstacles and to increase the understanding of how to plan and implement energy transitions towards renewable energies realistically, energy models are needed. However, only very few energy models are specifically built for use by developing countries. The large majority of the currently used energy models are developed in industrialised countries, based on their experiences and assumptions. Nevertheless, the assumptions and the data for energy systems of industrialized countries vary significantly from those of developing countries (1; 6). Therefore, these modeling approaches are not always able to present plausible results for developing regions. The main differences between energy systems of developing and industrialised regions are the following:

1) Differences in electrification rates and fuels use: In the western industrialized world, electrification rates account for about 100%. In developing regions, only a small percentage of the population has electricity yet, which will be subject to significant changes in the future (7; 8; 9). With 579 million inhabitants without electricity in 2000, India holds the world record of lowest electricity access (7). In the past, India's electrification schemes were mainly linked to rural development and irrigation (8). Also today, the Indian government ambitiously supports rural electrification programs (8). Figure 1 indicates that electrification rates tend to increase with rising income. For many developing countries, a rise in income is expected in the coming decades which might also positively effect the electrification rates. However, most energy models do not include statistics yet on how many people will get electrified in the future. Also, both commercial and traditional non-commercial fuel markets exist parallel in developing countries (11). Currently, a transition from traditional non-commercial fuels to commercial fuels is ongoing (12). For developing countries, different fuels need to be included in energy models.

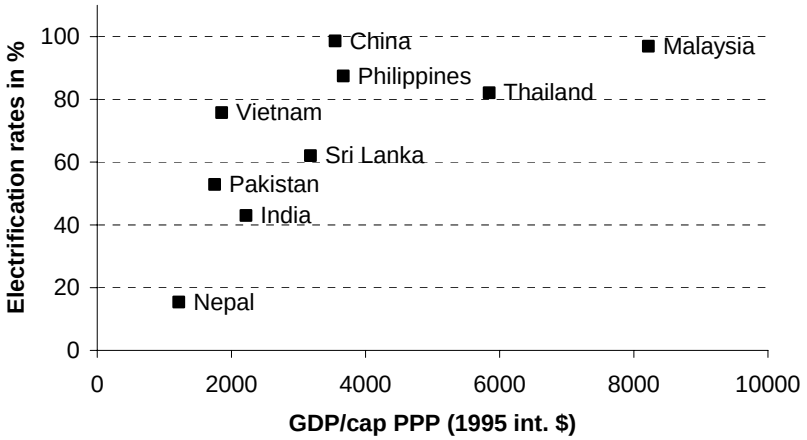

Figure 1: Electrification rates in percentage in developing regions plotted against GDP per capita for the year 2000 for Asian countries. Data source: IEA, 2002a (7) and World Bank WDI, 2005 (13).

2) Economic structural change: Most energy models assume that developing economies will develop as industrialised economies did in the past by a decline of the agricultural sector, a heavily growing industry and a later shift to the service sector. However, statistics show different trends (13; 14). For some countries, it has been observed that an early shift towards the service sector can occur which accounts for different energy patterns than foreseen by most energy models (14; 13). Figure 2 analyses data on value added and energy intensity for India and China. The graph shows staggering differences in economic structure between India and China. By 2002, the Indian economy was almost half services-based, while China relied for 50% on industry. Energy intensity decreases in both countries, in China faster than in India.

Also, due to the Clean Development Mechanism, enhanced possibilities for leapfrogging exist (15; 16). This means that future energy generation and consumption in developing countries will not necessarily follow the same patterns as in the western world.

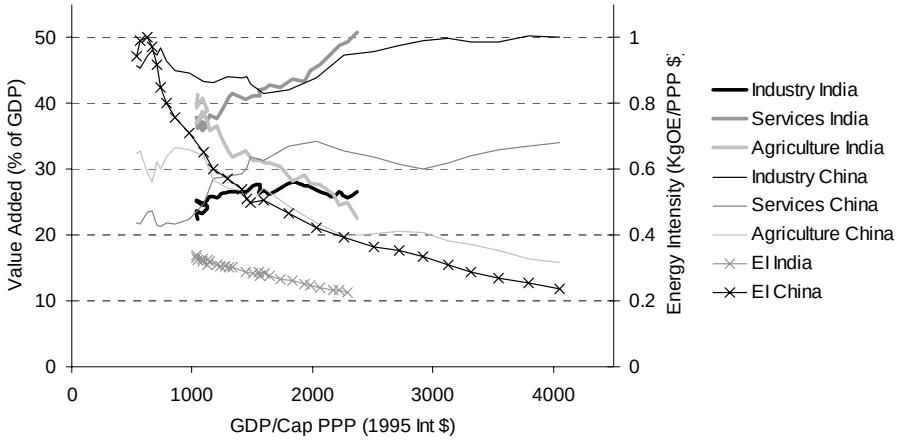

Figure 2: Right, value added and primary energy intensity vs. GDP/Capita for India and China between 1975-2002. Data source: World Bank WDI, 2005 (13)

3) Different policy frame: Policies differ significantly between industrialised and developing countries. In many developing countries, the power industry was formerly dominated by heavy state regulation, administrative and financially inefficient monopolies and the absence of legislative and policy frameworks for effective regulation (10; 6). During the 90s, reforms to commercialise the power sector took place in many developing countries based on the World Bank's experience in OECD countries (6). Due to significant differences between the political, economic and legal systems of developing and developed countries the reforms have not been successful (6; 17). After these reforms, especially India is facing a serious crisis of the power sector including an increasing gap between supply and demand and a growing risk of bankruptcy (18). Analogously to industrialised country's policy reforms, their energy models are not suitable for aiming at solving developing countries´ policy problems.

Discussion

We found that developing countries' energy systems deviate from developed countries energy systems on key-issues that are relevant for global energy modeling such as differences concerning electrification rates and fuel use, policy frames and economic structural change. We also found that often these key-issues are not fully taken into account by global energy models. However, from a questionnaire on energy modeling and development issues, we know that issues of development are considered very important by energy model developers (19). A number of energy models are currently undergoing updates for a better inclusion of development issues and it is expected that greater emphasis will be given to these issues in future energy modeling.

Conclusion

To conclude, energy models need to be especially suited for the needs and conditions of developing countries´ energy systems. New energy models and new updates to existing models should be made for developing countries to incorporate differences in electrification rates and fuel use, policy frames and economic structural change. The authors have done research on the future of developing countries´ energy systems (20) and how this is modelled

in present-day energy models (19). The insights of this research will be used by the authors to build a model especially made for energy transitions in developing countries. This may contribute to planning and implementing the transition towards renewable energies realistically.

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We would like to thank Bas van Ruijven, Bert de Vries, Detlef van Vuuren and Jeroen van der Sluijs from RIVM and the University of Utrecht who contributed to the results of this paper by means of collaboration for a joint article on modeling energy and development (19).

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